

Novel Design Tools for Prepreg-Platelet Molding Compound

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Composites Manufacturing
& Simulation Center

Development of Novel Materials and Processes for High-Rate Automotive Applications



Dow's Prepreg Platelet Molding Compound (PPMC)

Goals

- High performance & high rate
- Moldable to complex geometries
- Design for automated handling
- No waste

Challenges

- Mesostructure variability
- Anisotropic flow during molding
- Control of charge orientation
- Mesoscale close to part scale



Target Application: Ford Liftgate Inner

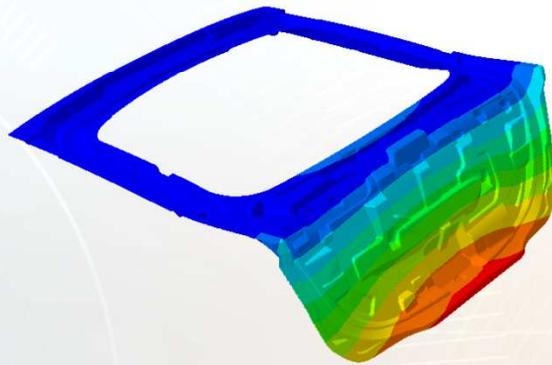


Manufacturing-Informed Performance

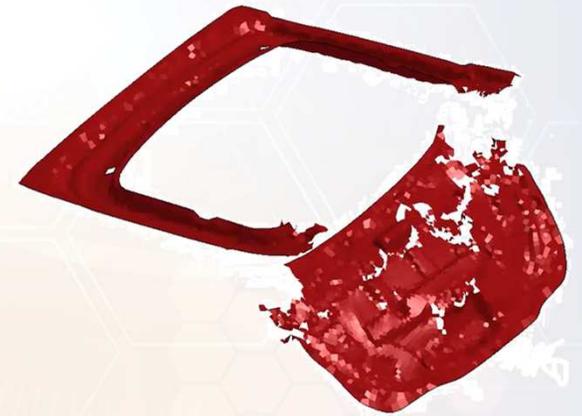
Flow Orientation



Static Stiffness



Crash Performance

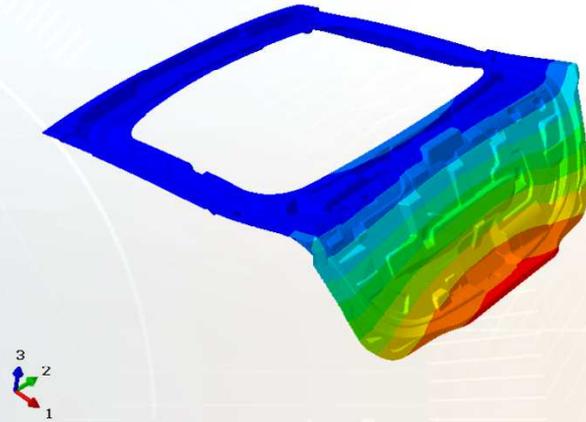


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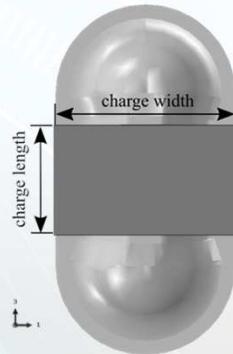


Flow Geometries

Disc



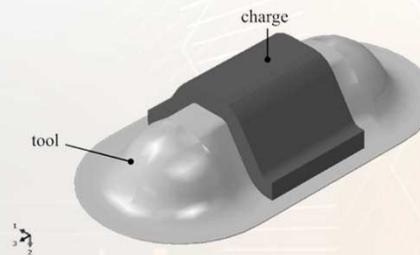
Double Dome



Liftgate



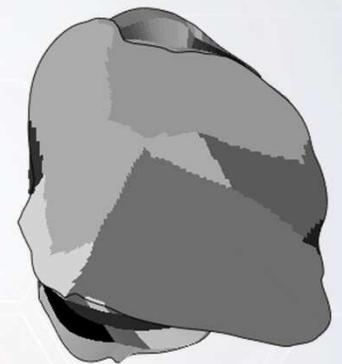
form mat onto tooling surface



Anisotropic Flow of PPMCs

Squeeze Flow Simulations

- Platelet size affects “smoothness” of orientation state



- Anisotropy reveals orientation state through smooth boundary evolution or coarse boundary evolution

Disc Experiments



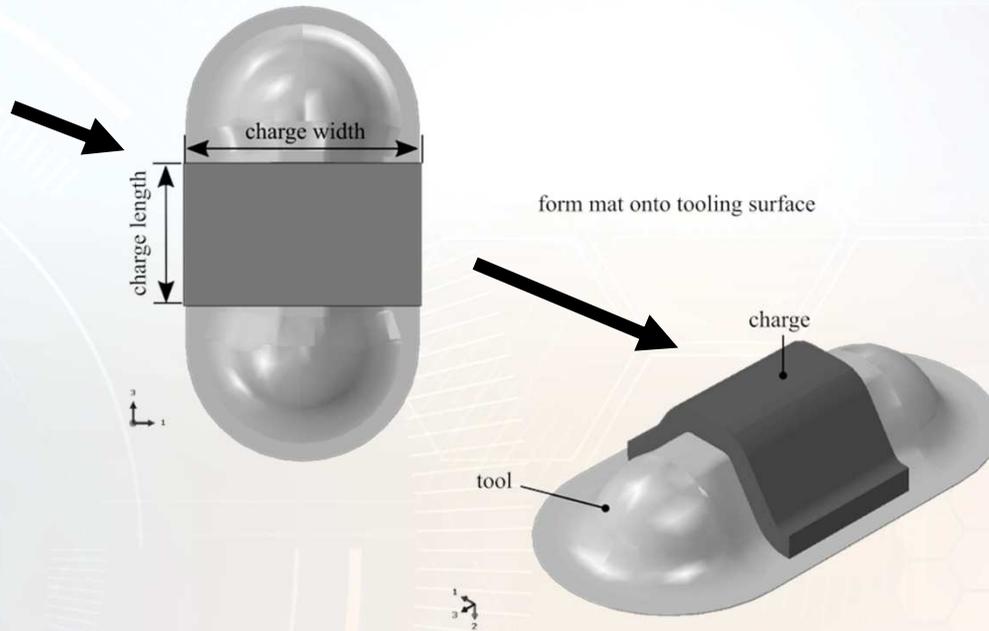
Platelet Dimensions 12.7 mm x 1.6 mm

12.7 mm x 12.7 mm

30 mm x 30 mm

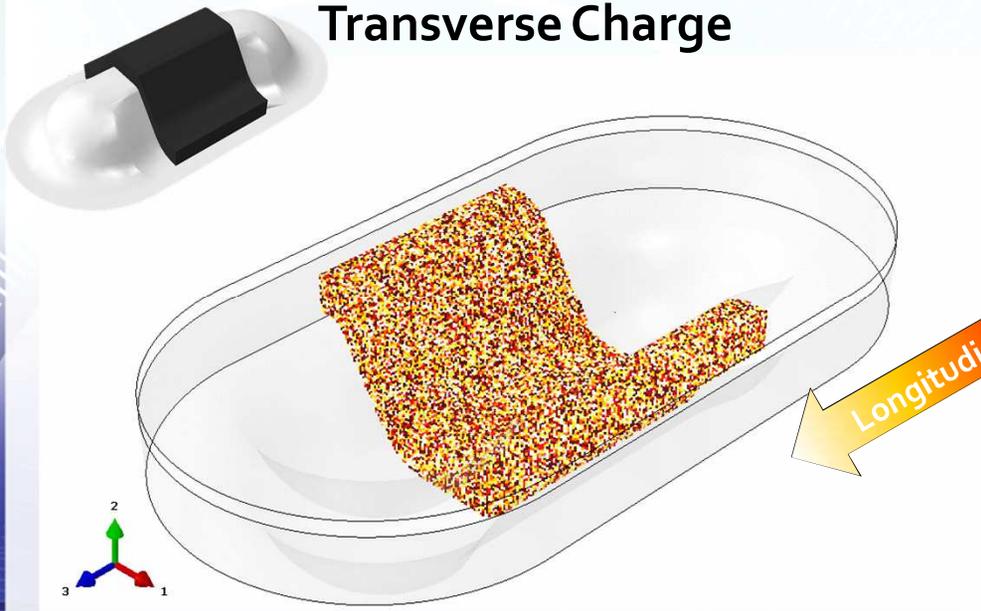
Double Dome Molding Simulation

PPMC material form



Orientation Engineering through Charge Placement

Transverse Charge



Experiences "1D" Flow
Greatly aligning the fibers in the flow direction

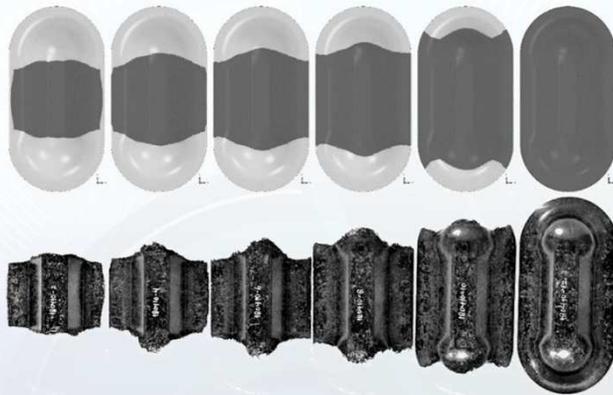
Axial Charge



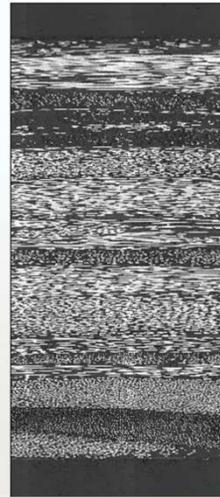
Experiences "2D" Flow
There is minimal effect on the fiber orientation
in the center region

Validation of Flow and Orientation Predictions

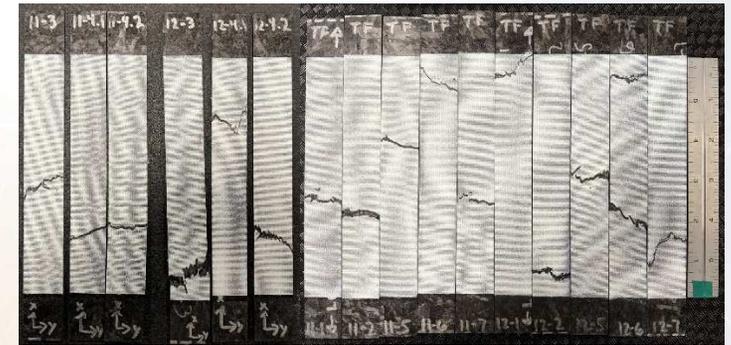
Flow Front



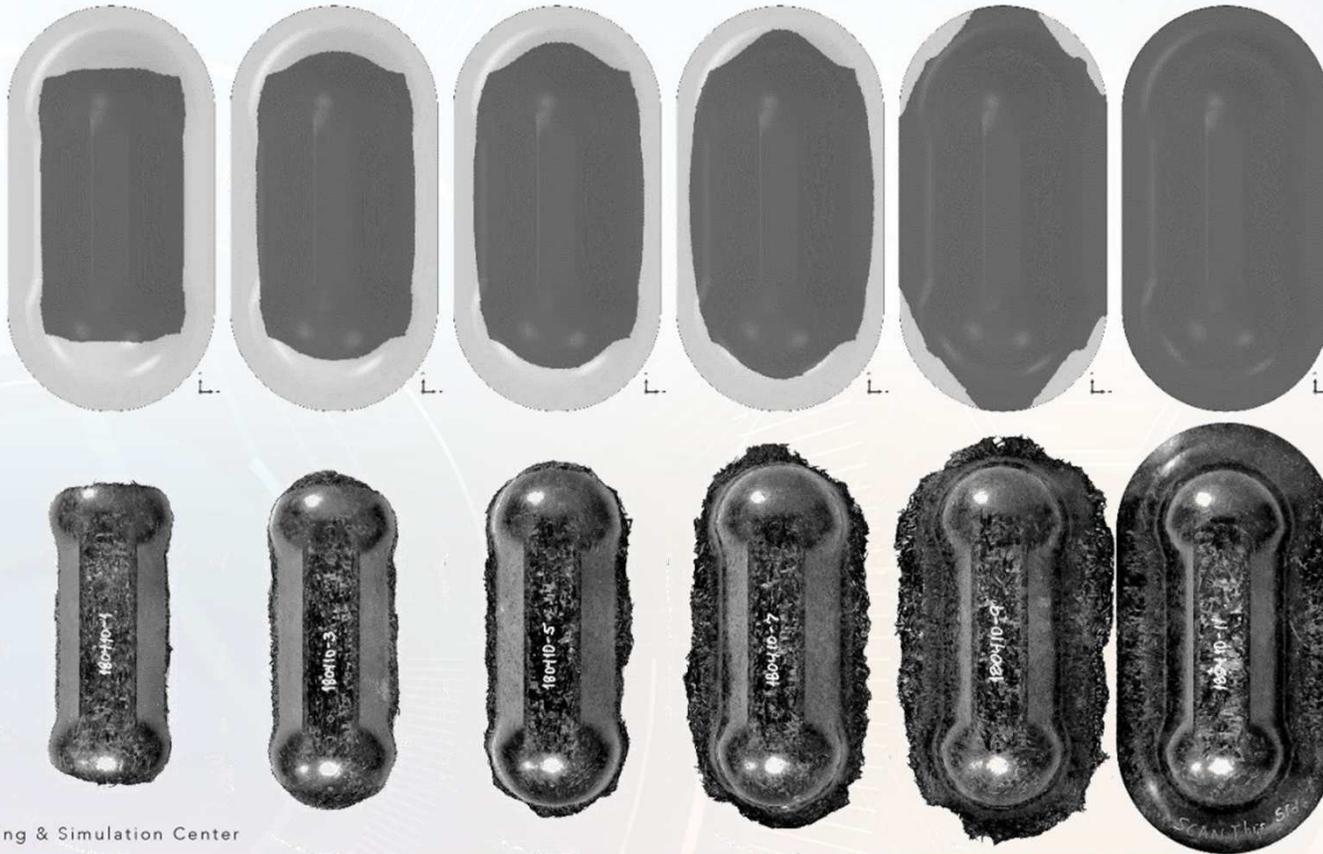
Orientation



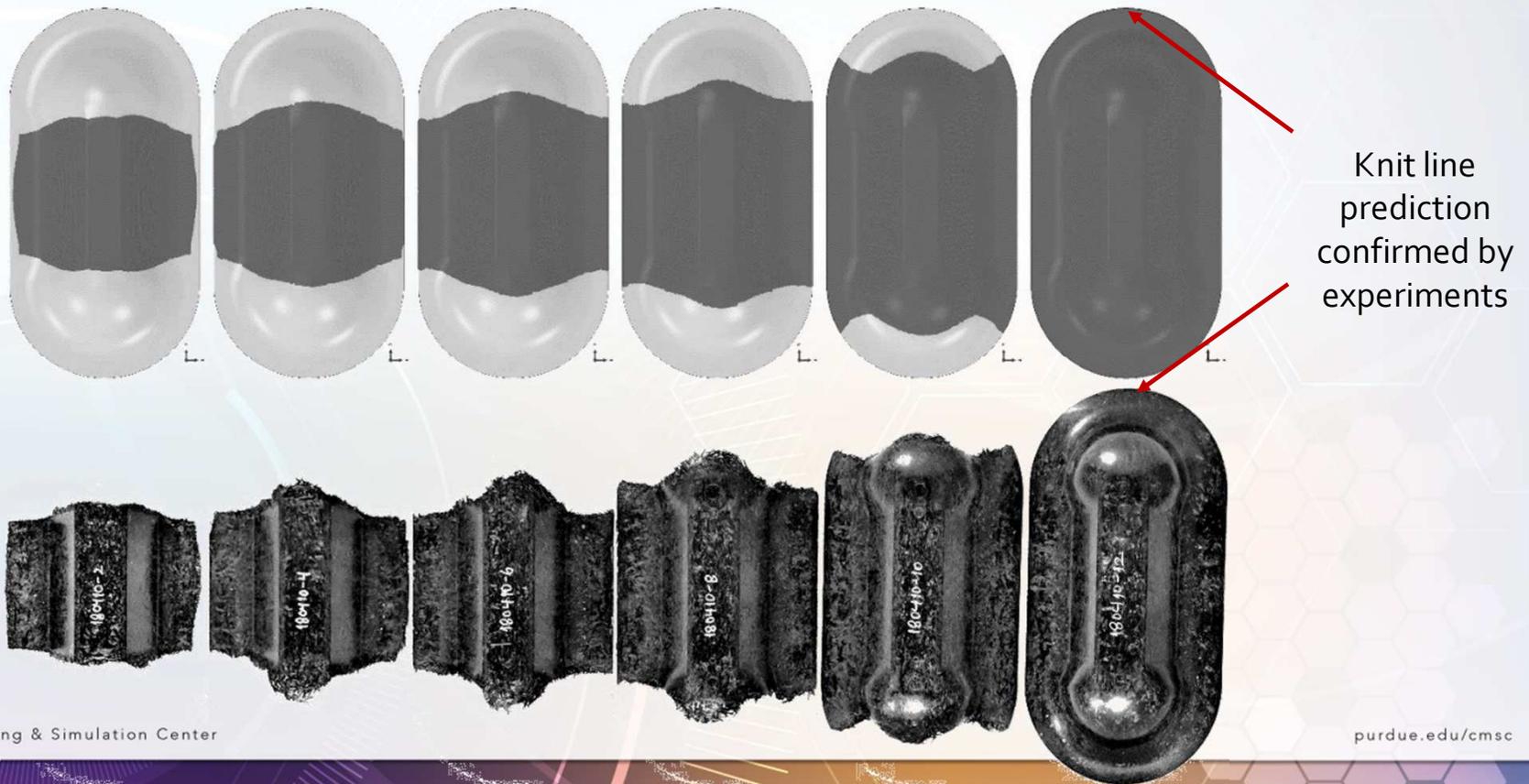
Flow-Induced Performance



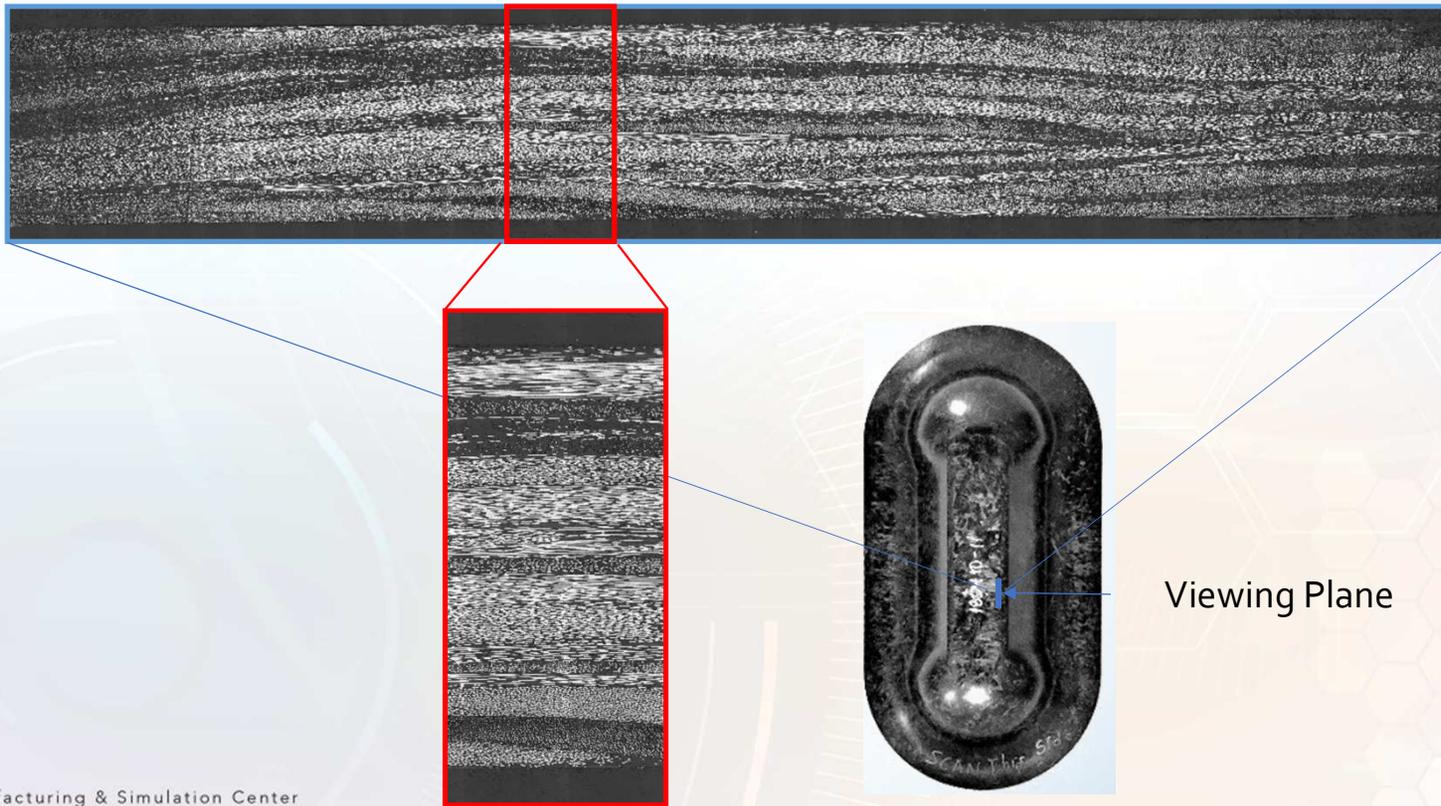
Axial Charge Results – Validation of Flow Front



Transverse Charge – Validation of Flow Front

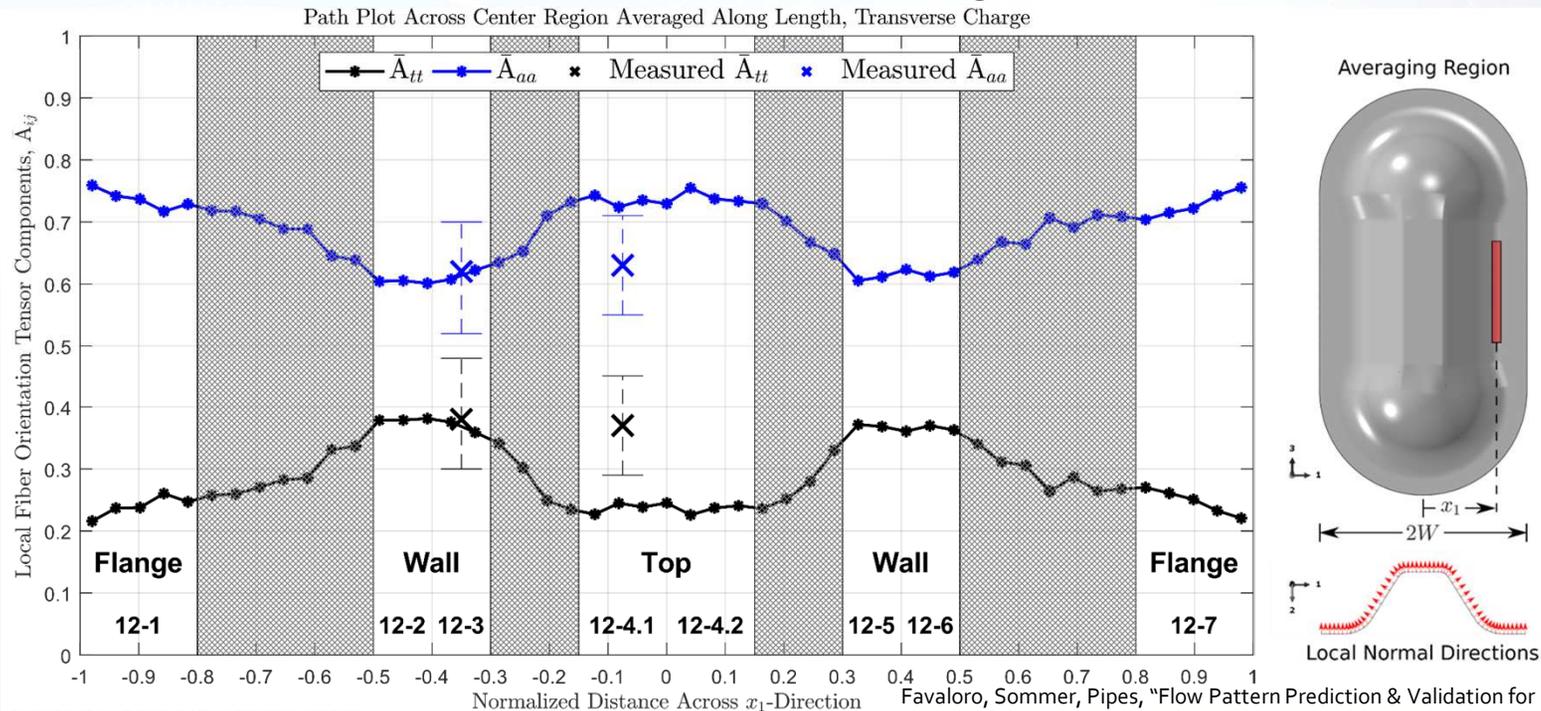


Validation of Predicted PPMC Orientation



Simulation Validation: Transverse Charge

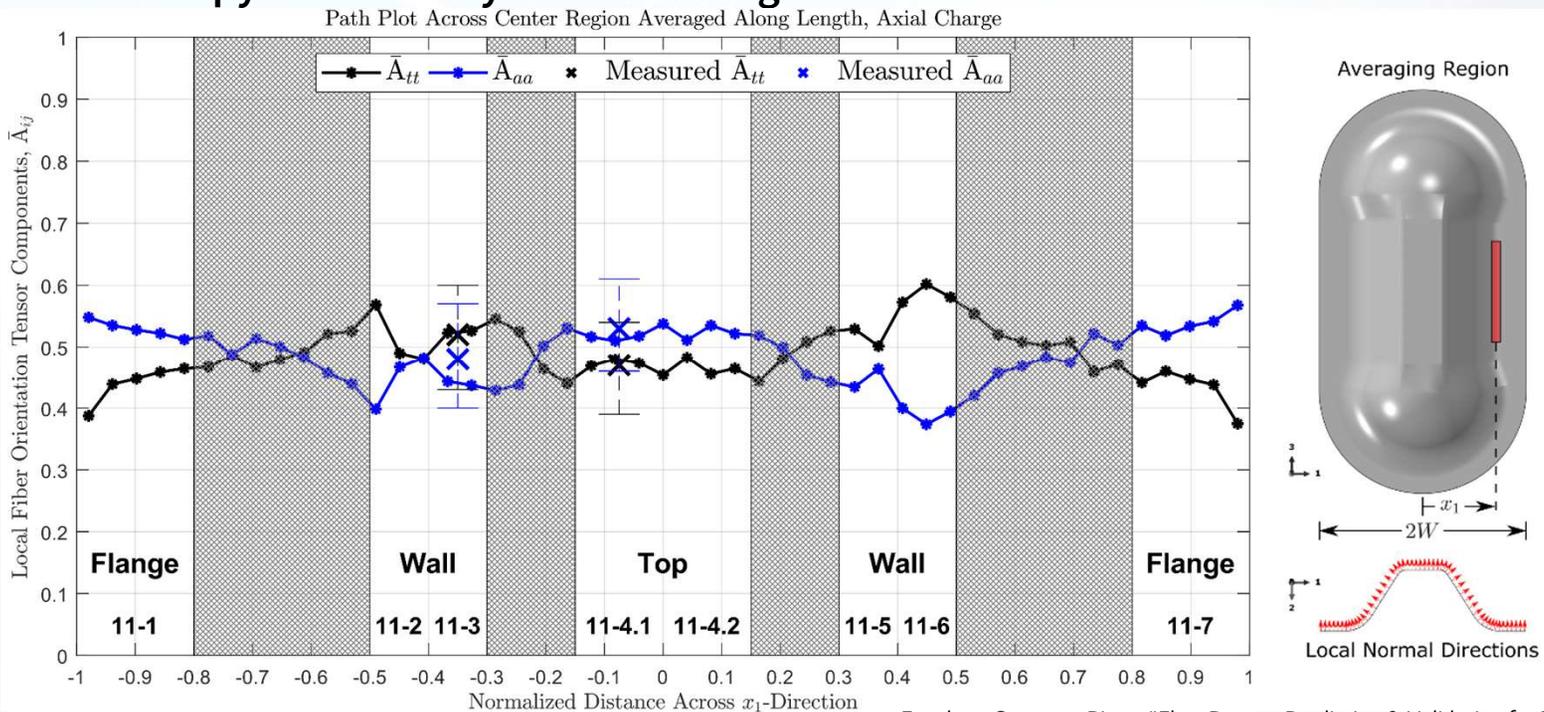
Ongoing experimental validation of blind orientation predictions from flow simulations using optical microscopy. Preliminary results show good correlation.



Favaloro, Sommer, Pipes, "Flow Pattern Prediction & Validation for Discontinuous Prepreg Using Anisotropic Viscous Flow Simulation" SPE ACCE 2018

Simulation Validation: Axial Charge

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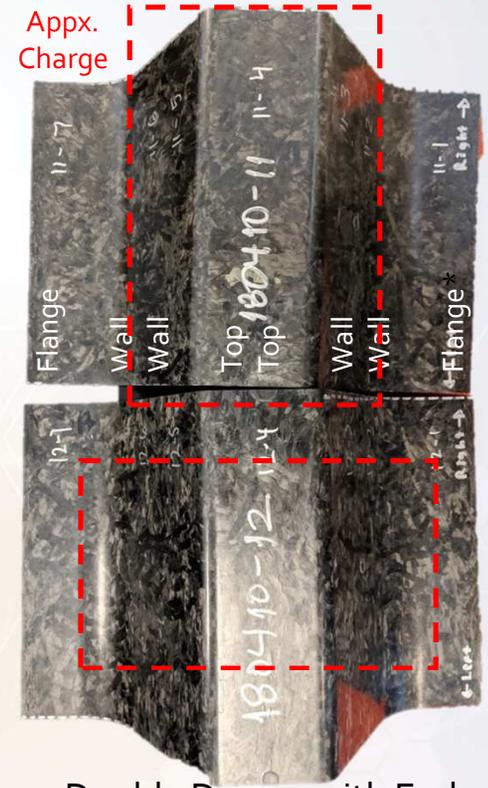
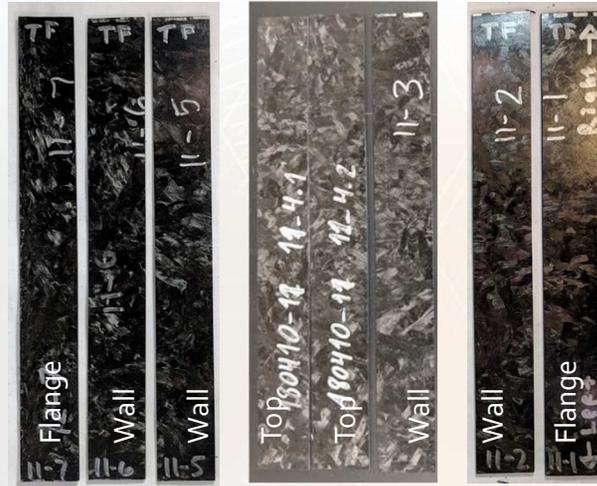
Double Dome Flow-Performance Validation

Transverse Charge



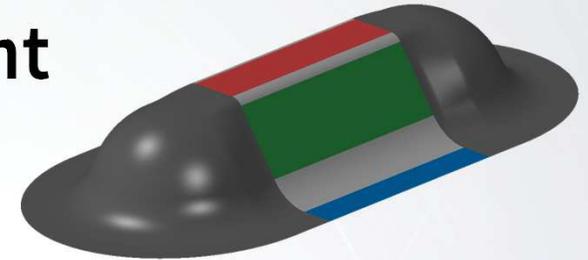
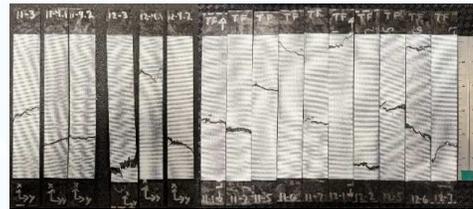
8x1"
coupons

Axial Charge

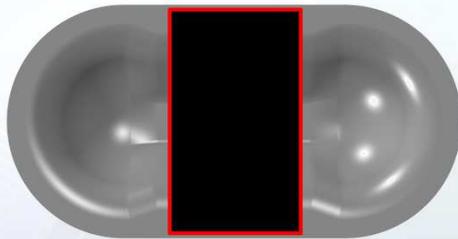


Double Domes with Ends
Removed

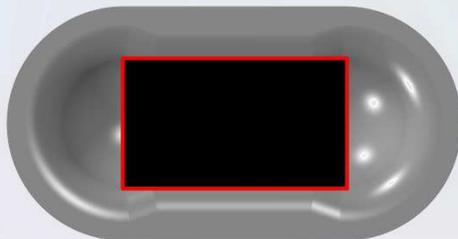
Charge Orientation Effect: Experiment



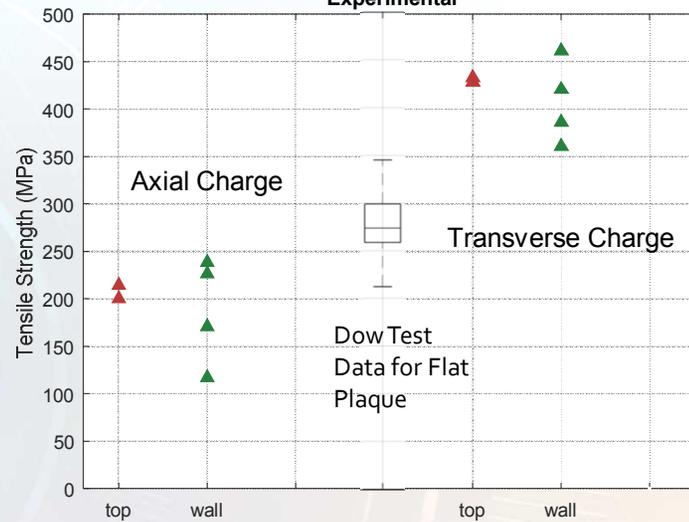
Transverse Charge



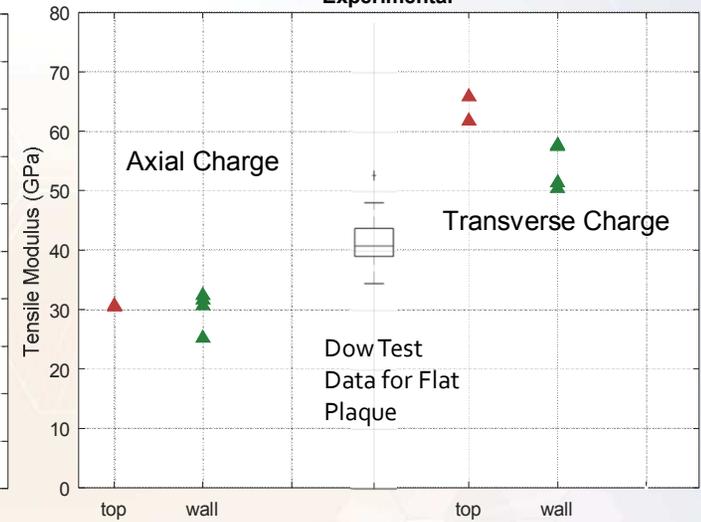
Axial Charge



Strength
Experimental

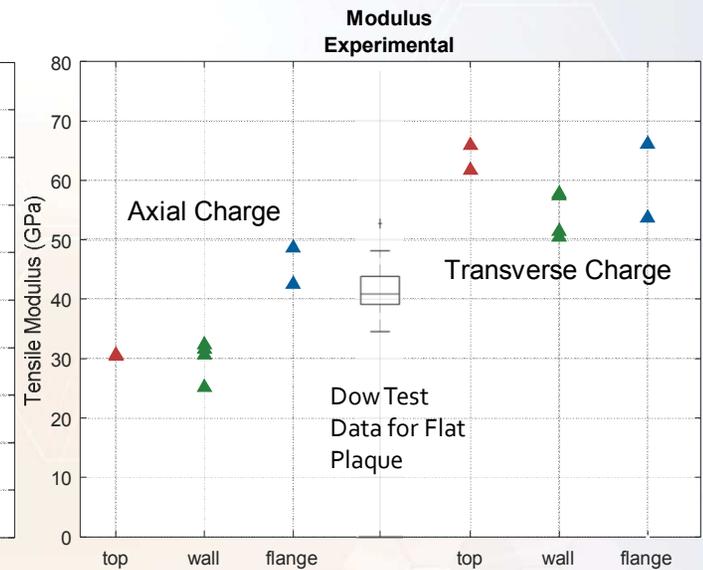
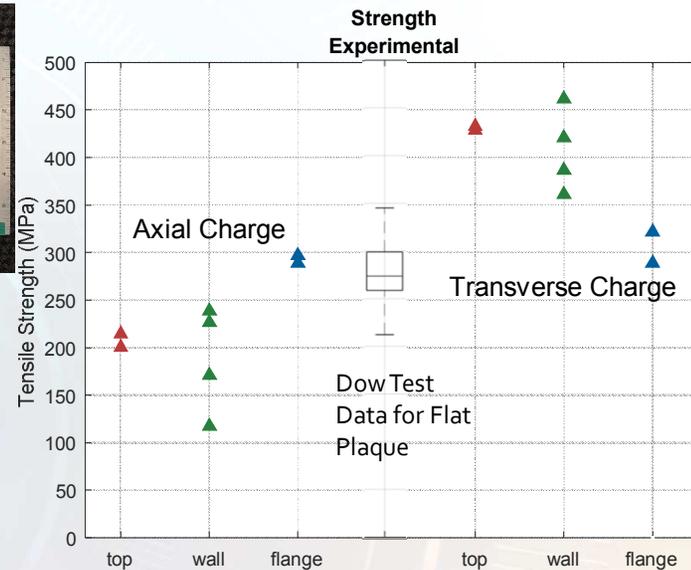
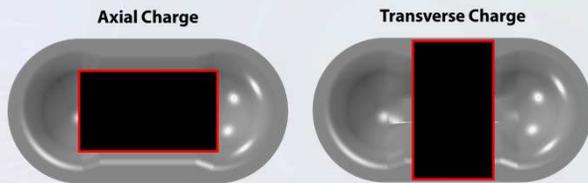
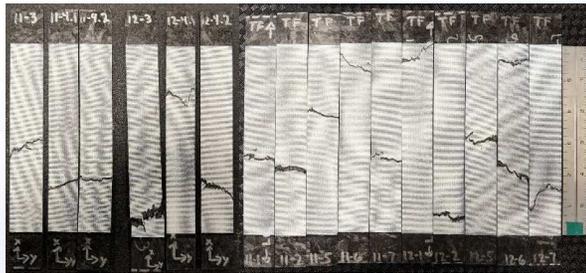
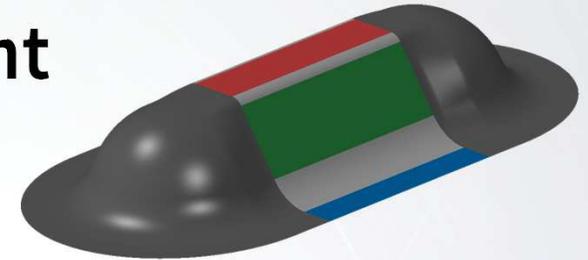


Modulus
Experimental



Charge Orientation Effect: Experiment

- Tested with no tabs, use emery cloth
- DIC data available for both sides, “front” data shown
- Transverse charge strength and stiffness greater than axial
- Flange properties higher in axial charge, lower/equal in transverse



Liftgate Flow Simulation



Liftgate Flow Simulation

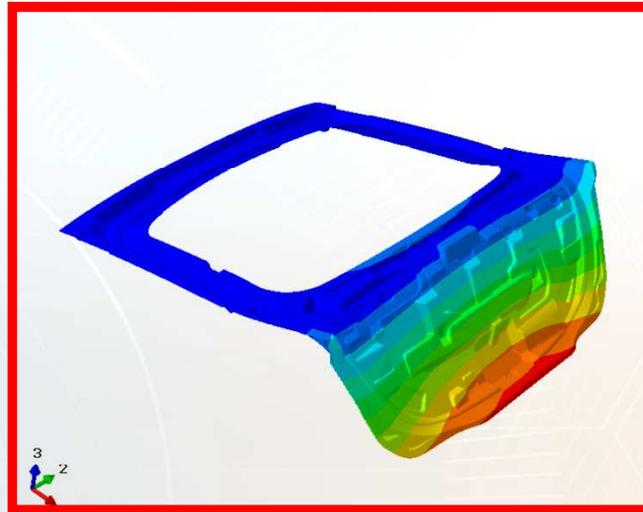


Manufacturing-Informed Performance

Flow Orientation



Static Stiffness



Crash Performance



Informing Structural Performance Models

Results from flow simulation

Structural model



Mapping

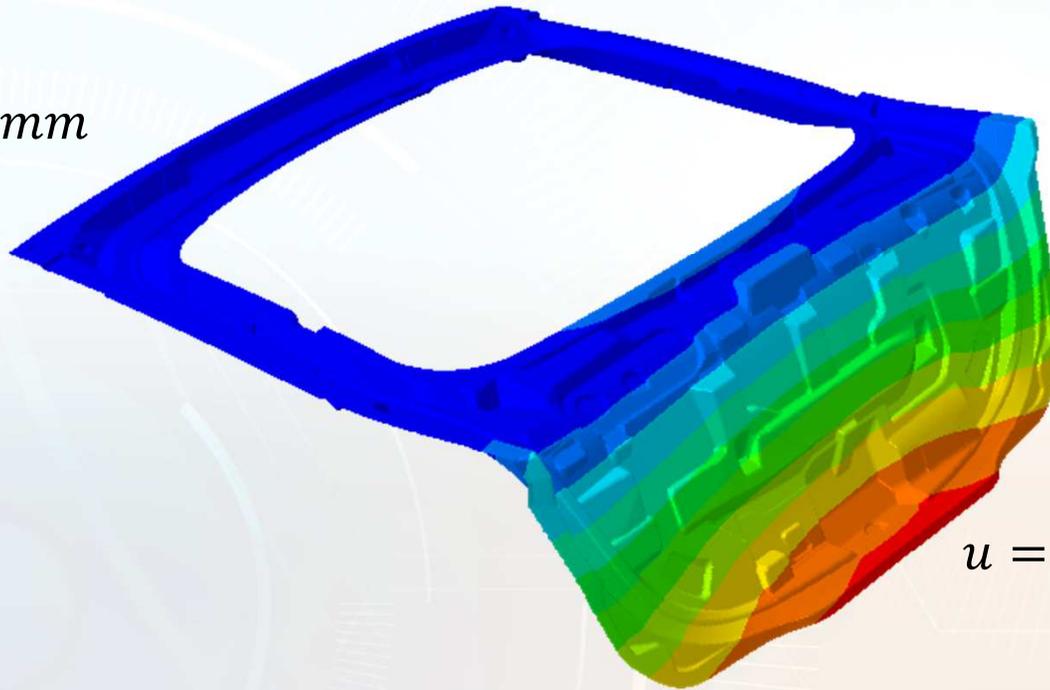


Static Stiffness Assessment



Manufacturing-Informed Stiffness Prediction

$u = 0 \text{ mm}$



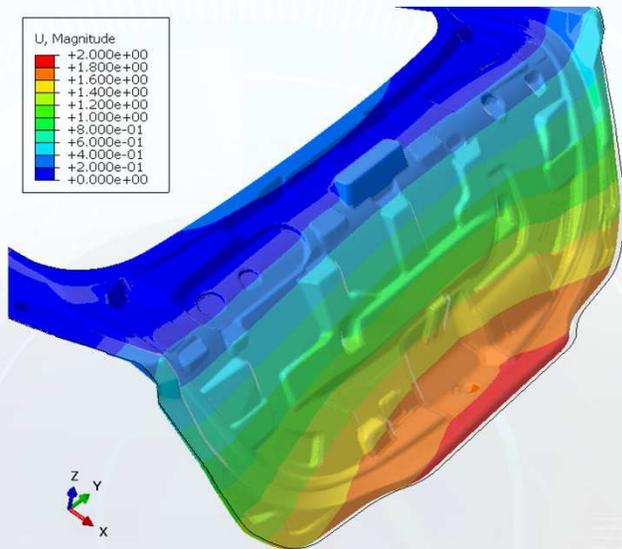
$u = 1.8 \text{ mm}$



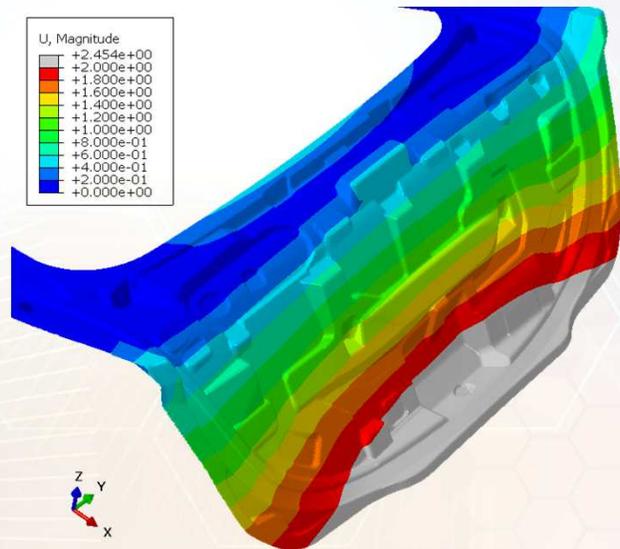
PPMC Liftgate Exhibits Superior Stiffness

PPMC with process-informed orientations

Aluminum inner of equivalent weight



$u = 1.8 \text{ mm}$



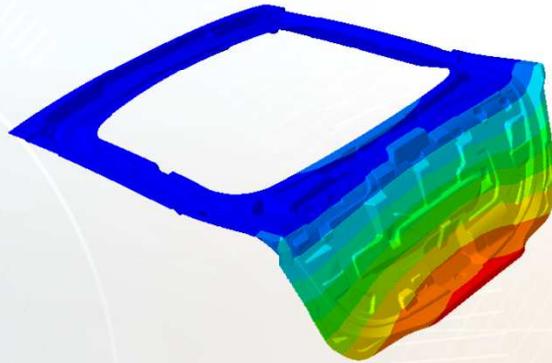
$u = 2.3 \text{ mm}$

Manufacturing-Informed Performance

Flow Orientation



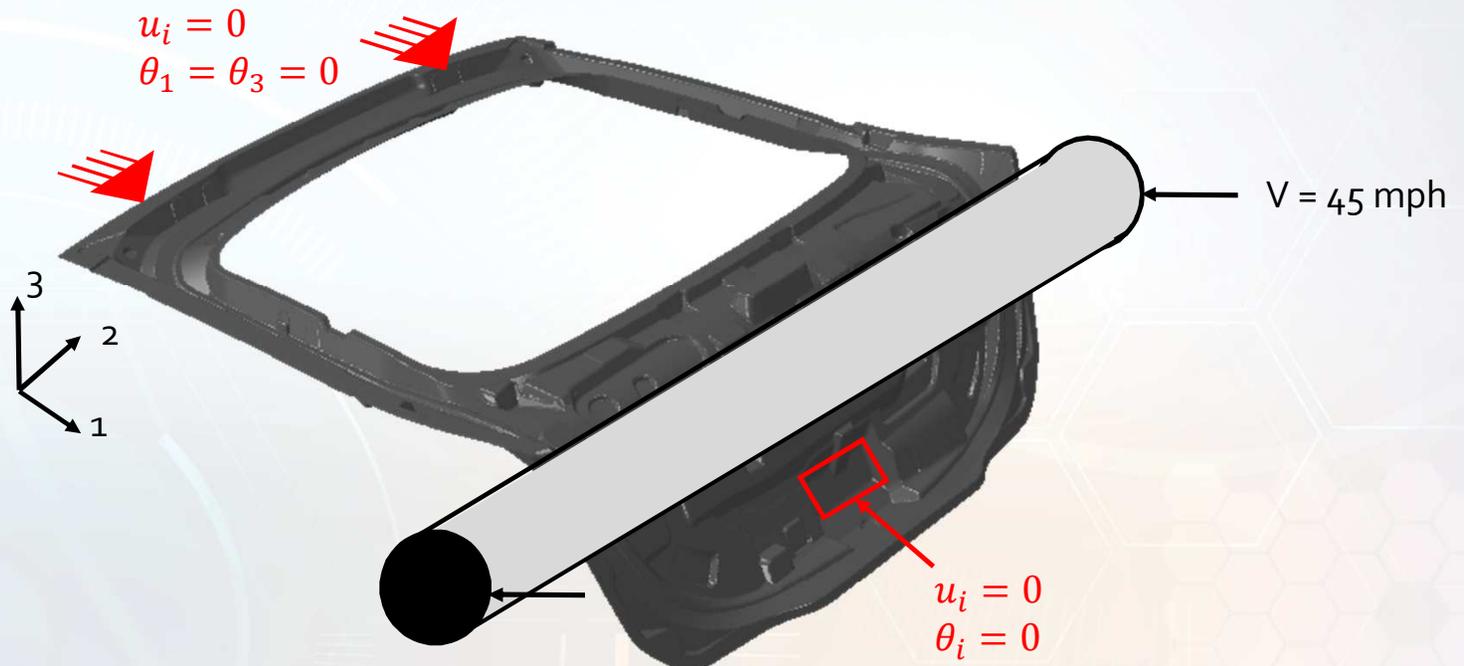
Static Stiffness



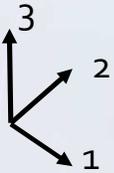
Crash Performance



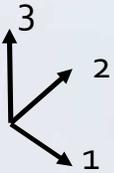
Crash Simulation of PPMC Liftgate



Successful Crash Simulation of PPMC Liftgate



Successful Crash Simulation of PPMC Liftgate

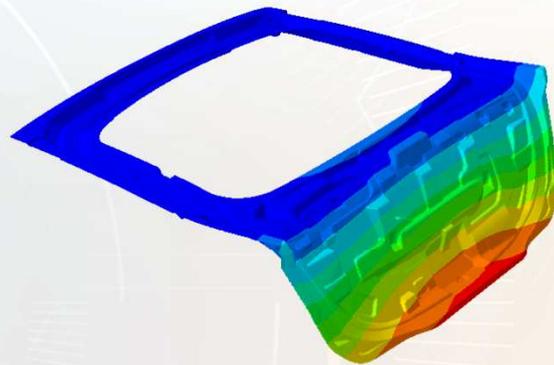


Enabling Manufacturing-Informed Design with Novel High-Rate Materials and Processes

Flow Orientation



Static Stiffness



Crash Performance

